

# CHARACTERIZATION OF CERVICAL SPINE IMPAIRMENTS IN CHILDREN AND ADOLESCENTS POST-CONCUSSION

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## ABSTRACT

**Background:** Patients with concussion may present with cervical spine impairments, therefore accurate characterization of cervical post-concussion impairments is needed to develop targeted physical therapy interventions.

**Purpose:** To characterize the type, frequency and severity of cervical impairments in children and adolescents referred for physical therapy after concussion.

**Study design:** Retrospective, descriptive study

**Methods:** A retrospective analysis was conducted for 73 consecutive children and adolescents who received cervical physical therapy following a concussion. Data was classified into six broad categories. The frequency and intensity of cervical impairments within and across the categories was reported.

**Results:** Ninety percent of patients demonstrated impairments in at least three out of five assessment categories whereas 55% demonstrated impairments in at least four out of five assessment categories. Of the five assessment categories, posture (99%) and myofascial impairment (98%) demonstrated highest impairment frequency followed by joint mobility (86%) and muscle strength (62%). Cervical joint proprioception was the least commonly evaluated assessment category.

**Conclusion:** High prevalence of cervical spine impairments was observed in the subjects included in this study with muscle tension, joint mobility, and muscle strength being most commonly affected. The categories of impairments examined in this cohort were consistent with the recommendations of the most recent clinical practice guidelines for neck pain. This study provides preliminary data to support the framework for a cervical spine evaluation tool in children and adolescents following concussion.

**Level of evidence:** Level 4

**Key words:** Cervicogenic, movement system, traumatic brain injury, youth

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## INTRODUCTION

Concussion is defined as a complex pathophysiological process affecting the brain which is induced by biomechanical forces.<sup>1</sup> Concussion is one of the most common athletic injuries in the United States and is a growing concern among children and young adults. In any given year, 43,200 to 67,200 of the 1.2 million total high school football players in the U.S. sustain concussions, with adolescents 15-19 years being most susceptible.<sup>2-4</sup> Of the 502,000 children and adolescents diagnosed with concussion between years 2001 and 2005, 35% were estimated to fall between the ages of 8-13 years.<sup>5</sup> Prevalence of post-concussion symptoms has been reported in previous studies with 90-92.2% of athletes experiencing headaches, 90% experiencing neck pain, and 68.9% experiencing dizziness.<sup>6-8</sup>

Cervical musculoskeletal attributes such as neck strength may represent a modifiable risk factor for concussion<sup>9,10</sup> and biomechanical similarities exist between concussion and whiplash injuries. Previous researchers have suggested a need for a structured cervical spine examination following a concussion.<sup>11,12,13</sup> This recommendation is further supported by the overlap between concussion symptoms and symptoms associated with whiplash injuries.<sup>1,12-14</sup> The transmission of forces to the head during a concussion may result in trauma to the cervical spine.<sup>1,15</sup> Axial loading, hyperflexion and hyperextension of cervical spine are the most frequently reported mechanisms of injury to the cervical spine associated with various sports such as football, hockey and wrestling.<sup>1,15</sup>

In previous studies, children demonstrated less cervical strength and greater head to body ratio than adults.<sup>16-18</sup> Therefore, children may not be able to generate sufficient tensile stiffness to control the head's response to impulsive loads,<sup>19</sup> and may experience greater head acceleration as compared to adults.<sup>20</sup> Moreover, it has been postulated that children exhibit reduced ability to efficiently dissipate energy from a head impact primarily due to underdevelopment of the neck and shoulder musculature.<sup>11</sup> Smaller and weaker cervical muscle attributes in children may predispose them to greater cervical impairments after a concussive event, and warrant a thorough characterization of cervical post-concussion impairments in adolescents.

Prior authors have acknowledged that patients may often experience post-concussion symptoms pertinent to the cervical spine.<sup>21-24</sup> Signs and symptoms such as decreased range of motion, muscle tenderness, headaches, stiffness and radicular symptoms have been reported to occur post-concussion.<sup>22</sup> In previous studies more than 50% of patients continue to demonstrate symptoms such as headache, fatigue and dizziness even after the expected recovery time-frame post-concussion.<sup>23,25</sup>

A comprehensive multifaceted approach to evaluation and treatment of post-concussion impairments must acknowledge heterogeneity of impairments including central and autonomic nervous system impairments, cervical and thoracic spine impairments, and vestibular and oculomotor impairments. A variable combination of impairments across these categories contributes to the overall constellation of symptom.<sup>12,23,26</sup> For the best possible outcomes, physical therapy interventions must be directed toward specific impairments that are found during evaluation.<sup>23</sup> Developing impairment-directed therapeutic interventions would result in supporting progression to subsequent clinical trials to establish efficacy and enhance practice patterns.<sup>23,27</sup>

Despite the consensus that a thorough cervical examination is needed in patients with concussion,<sup>12,26</sup> the evidence for characterization of common cervical impairments after concussion in children and adolescents (i.e.  $\leq 18$  y) is sparse.<sup>28,29</sup> Although the most recent Clinical Practice Guidelines (CPG) for neck pain thoroughly reviewed the literature surrounding neck pain and associated cervical impairments, studies including children (i.e.  $< 18$  years) were excluded from the CPG.<sup>30</sup> Moreover, authors of the CPG recommend further research into treatment of patients with neck pain because of a concussion.<sup>30</sup> Accurate characterization of the type, number and severity of cervical post-concussion impairments is needed for the development of targeted interventions.<sup>12,21</sup> The purpose of this study was to characterize the type, frequency and severity of cervical impairments in children and adolescents after concussion. This study will provide valuable insights into the extent and nature of cervical spine impairments post-concussion that may provide a foundation to develop targeted physical therapy interventions.

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## METHODS

### Setting

The data for this study was retrospectively collected from the electronic medical records of a tertiary center specializing in comprehensive interdisciplinary management of for patients with concussion. The study was approved by the Institutional Review Board at University of Michigan.

### Design and participants

A retrospective chart review was conducted of 73 children and adolescents between the ages of 8 to 18 years who received cervical physical therapy following a concussion from January 1, 2017 to August 31, 2017. The patients were referred from emergency and athletic departments to the tertiary interdisciplinary concussion clinic by care providers. In the clinic, a physician performed symptom-based examination that included a brief cervical spine screening in patients complaining of neck pain at the time of their visit. A brief cervical screen included tests for ligamentous stability, followed by range of motion testing, palpation, or segmental mobility testing. Following examination, the patients were referred physical therapy for treatment of the cervical spine if indicated. Seven physical therapists performed examinations on patients, and recorded their findings. Upon inception of the concussion management program in this tertiary clinic, all seven treating therapists were trained to standardize administration of the tests and used standardized assessment forms as a measure of quality assurance. Demographic and clinical information was retrieved from electronic medical records.

### Procedures

A data extraction sheet was developed by two investigators (DT and BA). The investigators independently extracted data for five random patients and the extracted data was compared to ensure consistency in data extraction. After ensuring quality of the extracted data, the primary investigator (DT) completed the remaining data collection. Assessment data from the first physical therapy visit was extracted. In the event that a full assessment was not completed due to excessive increase in patient's symptoms, the subsequent two visits were screened to extract additional assessment data.

### Demographic, injury and care process data:

Demographic and injury characteristics were retrieved from electronic medical records. These characteristics included age, gender, primary sport(s), prior history of migraine or prior learning disabilities, date of sustaining concussion and mechanism of injury. In addition, the date of first medical visit, date of first physical therapy visit, total number of physician visits and total number of physical therapy visits were also collected.

### Self-reported symptoms and disability:

Sports Concussion Assessment Tool 3<sup>rd</sup> edition (SCAT-III) symptom evaluation checklist: SCAT-III is a concussion evaluation tool that was developed from the original SCAT to make decisions regarding return to play.<sup>31</sup> This study utilized the symptom evaluation checklist of the SCAT-III. The data on symptom severity score was collected on 22 concussion related symptoms including cognitive, physical, sleep and affect related symptoms using a Likert scale (0 = none, 6 = severe), where higher scores indicated greater symptom severity (maximum possible score = 132).<sup>26</sup>

Neck disability index (NDI): The NDI is a self-reported measure with 10 items that is used to record perceived disability in patients with neck pain.<sup>32</sup> The NDI scores were interpreted as described by Vernon and Mior<sup>33</sup> where score of 0-4 indicated no disability, 5-14 mild disability, 15-24 moderate disability, 25-34 severe disability and scores above 35 indicated complete disability with a maximum possible score of 50.<sup>33,34</sup>

### Screening for ligamentous instability:

Results of special tests for upper cervical ligamentous instability including tests for alar ligament and transverse ligament were collected.<sup>35</sup>

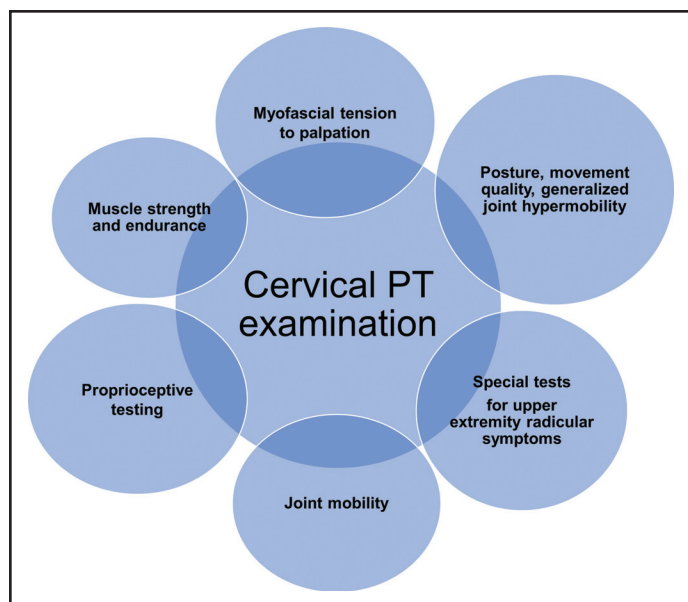
Test for alar ligament: The test for alar ligament was performed with patient in a seated position.<sup>36</sup> The examiner's palm was placed on the forehead and index finger of the other hand was placed on the tip of spinous process of second cervical vertebra. The examiner then side bends and rotates the patient's head to the left or right while stabilizing C2. The test is considered positive for instability if movement between head and neck is observed.<sup>35,36</sup> This test

demonstrates high specificity (0.88-1) and moderate to high sensitivity (0.54-0.84) to detect ligamentous instability in patients with whiplash disorder.<sup>37,38</sup>

**Test for transverse ligament:** The test for transverse ligament was performed with the patient in supine position with examiner supporting the head. Examiner's index finger was placed between the occiput and spinous process of C2 vertebra. The head and C1 vertebra was then lifted anteriorly, not allowing either flexion or extension and the position was maintained for approximately 15 seconds. The test was considered positive if the patient exhibited nausea/vomiting, reported lip paresthesia, lump in the throat sensation, dizziness, headache or muscle spasm.<sup>39</sup> This test demonstrates high specificity (0.96-1) and moderate to high sensitivity (0.51-0.79) for patients with whiplash disorder.<sup>37,38</sup>

### Cervical Physical Therapy Examination

Cervical physical therapy assessment data were classified into six broad assessment categories. These assessment categories included posture, movement quality and generalized joint hypermobility (GJH), myofascial tension to palpation, joint mobility, muscle strength and endurance, proprioception, special tests for upper extremity radicular symptoms. (Figure 1)



**Figure 1.** Assessment categories included in cervical examination.

### Posture, movement quality, Generalized Joint Hypermobility (GJH):

**Posture:** Forward head posture, scapular anterior tilt and increase in thoracic kyphosis were the dysfunctions assessed by observation using an ordinal scale (no/mild/moderate/severe). Posture was classified as impaired if a patient has one or more of these dysfunctions. As a part of continuous quality assurance initiative in our clinic, the treating therapists underwent a training to standardize the evaluation procedure and to ensure inter-rater reliability using standardized patients. For assessment of posture, treating therapists demonstrated high reliability as indicated by 100% percent agreement in their assessment of postural abnormalities.

**Scapulohumeral rhythm:** Scapulohumeral rhythm is defined as the ratio of glenohumeral movement to scapulothoracic movement during arm elevation.<sup>40</sup> Scapulohumeral rhythm was assessed by observation using an ordinal scale of good (symmetric, full motion), fair (symmetric, not full motion) and poor (asymmetric, not full motion). In this study, scapulohumeral rhythm was considered abnormal if it was rated as fair or poor.

**Beighton Scale:** Greater than normal joint laxity across joints has been associated with a range of connective tissue disorders. Evidence suggests that children with generalized joint hypermobility (GJH) experience greater pain as compared to those without hypermobility. Morris and colleagues reported that adolescents with GJH had higher odds of musculoskeletal pain after participating in sports as compared to children who did not have GJH (Odds ratio = 2.51 (1.48-4.26)).<sup>41</sup> Also, GJH has been reported to contribute to chronic pain, fatigue and impaired proprioception in children thereby limiting their activity and participation.<sup>42</sup> Beighton test is a measure to evaluate GJH in children.<sup>43</sup> The scale assesses items including passive dorsiflexion of 5<sup>th</sup> metacarpophalangeal joint, passive elbow hyperextension, passive knee hyperextension (all three bilaterally measured by goniometry), bilateral passive opposition of the thumb to the flexor side of forearm and forward flexion of the trunk with knees straight.<sup>43,44</sup> It is scored on a 0-9 scale where a score of 5 or greater indicates GJH.<sup>35,45</sup>

Test results were interpreted as presence (a score of  $\geq 5$ ) or absence (a score of  $< 5$ ) of GJH. The Beighton Scale demonstrates good intra-rater (ICC = 0.96-0.98)

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and fair inter-rater (ICC = 0.73) reliability and has been documented as a valid measure to assess GJH in healthy children and adolescents.<sup>44,45</sup>

### **Myofascial tension to palpation:**

Tension to palpation: For this study, muscle tension to palpation was defined as a persistent painful contraction that could not be completely relaxed by voluntary effort.<sup>46</sup> Data on myofascial tension to palpation (no, mild, moderate, severe) for specific cervical muscle groups and individual muscles (paraspinals, suboccipitals, upper trapezius, levator scapulae, sternocleidomastoid and scalenes) was collected for both right and left sides. Presence or absence of tension to palpation was assessed on a 0-3 Likert scale (0 = No tension, 3 = severe tension). If tension was present, then the data was further categorized as unilateral or bilateral presence of tension to palpation for each muscle group. Palpation of muscle has previously been shown to demonstrate discriminant validity and acceptable reliability (ICC = 0.40 – 0.84) using different Likert scales.<sup>47-49</sup> Additionally, the pilot data indicated that treating therapists demonstrated good agreement between their scoring of palpation tests. (Percent agreement = 83.33%).

### **Joint mobility:**

Range of motion (ROM) and pain: Data on active range of motion for cervical spine for flexion, extension, side bending and rotation (right and left) were recorded using cervical range of motion assessment device (CROM). Data was classified using previously published percentile values.<sup>50</sup> Consistent with previous studies that used a median split to define high and low performers, scores less than the median (i.e. < 50<sup>th</sup> percentile) in each direction were considered abnormal.<sup>50,51</sup> The frequency of abnormalities was reported for each direction. Additionally, the total number of abnormal directions was reported for each patient. Neck pain associated with cervical spine movements was recorded as presence or absence of pain (yes/no) with movement. The frequency of pain was reported for each movement, and the total number of painful directions was reported for each patient.

Segmental mobility testing: Segmental mobility of the cervical spine was assessed in prone position using posterior to anterior glide.<sup>52,53</sup> Each segment was classified as hypomobile, hypermobile, or normal). The data for cervical spine was further classified

according for the upper cervical (C0- C2) and the lower cervical spine (C3-C7). Based on these scores, the overall mobility was rated as hypomobile (hypomobile for one or more segments), normal (normal for all segments), or hypermobile (hypermobile for one or more segments).<sup>54</sup> Patients that presented with hypermobility in some segments but hypomobility in others were reported as mixed findings. Previous studies have reported variable reliability for segmental mobility tests.<sup>55-57</sup> To ensure consistency, reliability among treating therapists was calculated and acceptable reliability for segmental mobility tests (percent agreement = 66-100%) was found.

Rib mobility: While the patient lay in supine position, the rib mobility was tested. The therapist was feeling for the anteroposterior movement of the ribs as the patient inhaled and exhaled. The therapist quantified any restriction or asymmetry in rib motion.<sup>58</sup>

### **Muscle strength and endurance:**

Manual Muscle Test (MMT): This consisted of manual muscle testing of upper, middle and lower trapezius, rhomboids and cervical flexors (i.e. Longus Colli and Sternocleidomastoid) on a 0-5 point scale (0 = no perceptible muscle contraction & 5 = muscle holds test position against “full pressure”).<sup>59,60</sup> The data were classified as normal (5/5) or abnormal strength (< 5/5). Muscle strength was considered impaired if deficits were observed on MMT.<sup>60</sup>

Neck flexor endurance test (NFET): NFET is a timed test that is used to evaluate muscle endurance of cervical flexors. In this test, the patient maintained a chin tuck position in supine lying while holding the head 2.5 cm above the supporting surface.<sup>61,62</sup> The test was considered normal if the patient was able to maintain the required position for 38 seconds or more.<sup>63</sup> The NFET demonstrates moderate to good intra-rater (ICC = 0.67-0.93) and inter-rater (ICC = 0.69-0.96) reliability.<sup>61,64</sup>

Cranio-cervical flexor test (CCFT): The test consisted of five, 2-mm Hg progressive pressure increases from a baseline of 20-mm Hg to a maximum of 30-mm Hg. The patient was required to maintain isometric contraction for more than 10 seconds at each pressure level without substituting with superficial neck muscles.<sup>65</sup> The CCFT is a reliable test (ICC = 0.98-0.99)

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used to assess progressive activation and endurance of deep cervical flexors.<sup>65</sup>

### **Proprioceptive testing**

Joint position error test (JPET): This test measures the neck reposition sense reflecting afferent input from the neck joint and muscle receptors. The test was performed with patient in a seated position. The examiner established the neutral head position by focusing a laser pointer on the target. The patient received visual feedback for the neutral head position. The patient then performed active head rotation on one side with eyes closed and attempted to return to neutral head position. Final position of the laser point indicated error related to the center of the target.<sup>66</sup>

The test was performed for right and left rotation. An error of more than 4.5 degrees or 7 centimeters was considered as clinically significant.<sup>67</sup> The test was considered normal if the patient could return to the neutral head position with an error < 4.5 degrees or 7 cm in at least 2 out of 3 trials. The JPET demonstrates fair to excellent reliability (ICC = 0.35-0.9) in evaluating cervico-cephalic kinesthesia.<sup>68</sup>

### **Special tests for upper extremity radicular symptoms**

Spurling test: Spurling test was used to evaluate radicular symptoms. The patient performed lateral flexion and extension of the cervical spine. This was followed by application of axial pressure on the spine by the examiner. The test was considered positive if symptoms such as pain or tingling were reproduced.<sup>69</sup> Spurling test demonstrates acceptable reliability (Kappa = 0.60 (0.25-0.99))<sup>70</sup> and diagnostic accuracy (sensitivity = 52.9%, specificity = 93.8%) to evaluate radicular symptoms.<sup>71</sup>

### **Statistical analysis**

The demographic, injury and process of care data were expressed using descriptive statistics. All calculations were performed using Statistical Package for Social Sciences (SPSS) version 24.0 (SPSS Inc., Armonk, NY). The frequency of patients with a specific impairment as well as the number of impairments exhibited by each patient was presented using descriptive statistics i.e. frequency and percentages.

Spinal and rib mobility impairments, muscle strength and muscle guarding impairments were described as

frequencies and percentages. Active range of motion were expressed as percentiles compared to normative data.<sup>50,51</sup> Joint position error test was reported as normal or abnormal whereas Beighton test was reported according to the presence or absence of GJH. The distribution of myofascial tension, cervical and thoracic segmental mobility, and results on Spurling test were reported as percentages.

## **RESULTS**

### **Demographics, mechanism of injury and process of care**

Data from 73 patients was collected in this study. The average age of patients was  $14.6 \pm 2.5$  years (44% males). Thirty percent of patients sustained concussion after contacting the playing surface, 21% of the injuries were resulted from contact with another player whereas 18% of patients sustained injury from coming into contact with sporting equipment. Mechanism of injury was not sport-related for 29% of patients. Data on injury mechanism was not available for 3% of patients (Table 1).

Thirty-eight percent of patients had a history of migraine; more specifically, 51% of female patients (21/42) and 22% of male patients (7/32) had a history of migraine, 14% had attention deficit, 12% had a known learning disability, and 10% of patients had attention deficit hyperactivity disorder.

The median time to first physician visit following injury was 16 days and the median time taken for physical therapy evaluation following their first physician visit was six days (Table 1).

### **Self-reported symptom, cervical symptom disability, and screening for ligamentous instability:**

The average score on SCAT-III was 34 with scores ranging from 0- to 119) out of a possible score of 132. Patients reported an average of 14 individual symptoms (Range: 0-22) symptoms at initial physician visit. On NDI, 70% of patients reported disability attributed to neck pain (29% mild, 32% moderate, 8% severe and 1% complete) whereas only 15% of patients reported no disability. The NDI was not tested in 15% of the patients. All patients demonstrated intact cervical ligamentous integrity as

**Table 1.** Demographic, injury and care characteristics of participants.

N (% males)	73 (44)
Age in years, mean (SD)	14.6 (2.5)
Attention deficit, n (%)	10 (14)
Attention deficit hyperactivity disorder, n (%)	7 (10)
Learning disability, n (%)	9 (12)
History of migraine, n (%)	28 (38)
<b>Mechanism of injury N (%)</b>	
Contact with another player	15 (21)
Contact with playing surface	22 (30)
Contact with sporting equipment	13 (18)
Others (Non-sport related)	21 (29)
Not specified	2 (3)
<b>Process of care, Median (Min – Max)</b>	
Days to first physician visit following concussion	16 (1-237)
Days to first PT visit following physician visit	6 (0-380)
Number of physician visits	4 (1-11)
Number of physical therapy visits	3 (1-14)

indicated by negative findings on the tests for the alar and the transverse ligaments.

### Cervical physical therapy assessments

Posture (99%) and myofascial impairment (98%) demonstrated highest impairment frequency. Joint mobility was impaired in 86% of patients and muscle strength were impaired in 62% of patients (Table 2). Cervical joint proprioception was quantified only 29% of participants. Because proprioception was not examined in 71 % of patients, it was not included in the aggregated results quantifying the frequency of patients exhibiting impairments across the remaining five categories. Of the remaining five assessment categories, 90% of patients demonstrated impairments in at least three out of five categories whereas 55% demonstrated impairments in at least four out of five categories.

### Posture, movement quality, and GJH assessment

Posture abnormality was the most common impairment observed in this study. Forward head posture

was observed in 99% of patients, 86% of patients demonstrated increased thoracic kyphosis, and scapular anterior tilt was observed in 74% of patients (Table 3). Forty-eight percent of patients demonstrated abnormal scapulo-humeral rhythm (Table 3). GJH was the least common impairment as only 14% of patients demonstrated hypermobility as indicated by the findings of Beighton test (Table 3).

### Myofascial tension to palpation

Data on myofascial assessment revealed that 98% of patients demonstrated increased muscle tension. Upper trapezius (86%) and suboccipitals (83%) demonstrated highest percentage of patients with bilateral muscle tension followed by paraspinals, scalenes, levator scapulae and sternocleidomastoid (70-79%) (Table 4).

### Joint/Rib mobility

Cervical spine extension was found to be the most limited (i.e. < 50 percentile) movement (77%) followed by side bending (L = 55; R = 59%), flexion (45%) and finally rotation (L = 41; R = 42%). Overall, 90% of patients demonstrated impaired cervical AROM in one or more direction of movement (six directions = 15%, five directions = 12%, four directions = 18%, three directions = 19 %, two directions = 12%, one direction = 14%). Percentile scores for all AROM movements are reported in Table 5.

Twenty-three percent of patients reported neck pain with cervical flexion, closely followed by extension (22%) whereas up to 18 % of patients reported pain with side bending or rotation (Table 5). Twelve percent of patients demonstrated pain with movement in one direction, 11 % demonstrated pain with

**Table 2.** Frequency of patients exhibiting with impairments in the six assessment categories.

Impairment	N (%)		
	Abnormal	Normal	Not tested
Posture, movement quality & generalized joint hypermobility	72 (99)	0 (0)	1 (1)
Joint mobility	63 (86)	6 (8)	4 (6)
Myofascial tension to palpation	71 (98)	1 (1)	1 (1)
Muscle strength and endurance	45 (62)	8 (11)	20 (27)
Proprioception	14 (19)	7 (10)	52 (71)
Special tests for upper extremity radicular symptoms	0 (0)	71 (97)	2 (3)

**Table 3.** Impairment frequencies in posture, movement quality & generalized joint hypermobility.

Test	N (%)				
Posture					
	Mild	Moderate	Severe	Absent	Not tested
Forward head	29 (40)	37 (51)	6 (8)	0 (0)	1 (1)
Scapular anterior tilt	34 (47)	20 (27)	0 (0)	6 (8)	13 (18)
Increased thoracic kyphosis	34 (47)	28 (38)	1 (1)	5 (7)	5 (7)
Scapulohumeral Rhythm	Abnormal		Normal		Not tested
	35 (48)		12 (16)		26 (36)
Beighton Scale	Hypermobile		Normal		Not tested
	10 (14)		23 (31)		40 (55)

**Table 4.** Myofascial tension to palpation (N = 73).

Muscle groups	Bilateral TTP N (%)	Unilateral TTP N (%)	No TTP N (%)	Not tested N (%)
<b>Paraspinals</b>	57 (79)	4 (5)	8 (11)	4 (5)
<b>Suboccipitals</b>	60 (83)	3 (4)	6 (8)	4 (5)
<b>Upper trapezius</b>	63 (86)	2 (3)	5 (7)	3 (4)
<b>Levator scapulae</b>	52 (72)	3 (4)	12 (16)	6 (8)
<b>Sternocleidomastoid</b>	51 (70)	3 (4)	12 (16)	7 (10)
<b>Scalene</b>	53 (73)	4 (5)	13 (18)	3 (4)

TTP = Tension to palpation

**Table 5.** Percentile distribution for cervical active range of motion and pain with range of motion testing.

N (%)															
Percentile	<2.5	2.5	5	10	20	30	40	50	60	70	80	90	95	97.5	Missing
<b>Flexion</b>	0 (0)	6 (8)	0 (0)	0 (0)	8 (11)	6 (8)	13 (18)	1 (1)	4 (6)	12 (16)	4 (6)	3 (4)	5 (7)	6 (8)	5 (7)
<b>Extension</b>	14 (19)	11 (15)	3 (4)	15 (21)	1 (1)	3 (4)	9 (12)	2 (3)	0 (0)	7 (10)	2 (3)	0 (0)	0 (0)	1 (1)	5 (7)
<b>Left SB</b>	10 (14)	3 (4)	5 (7)	16 (22)	3 (4)	0 (0)	3 (4)	1 (1)	2 (3)	12 (16)	6 (8)	1 (1)	4 (6)	2 (3)	5 (7)
<b>Right SB</b>	12 (16)	6 (8)	4 (6)	2 (3)	17 (23)	2 (3)	0 (0)	2 (3)	1 (1)	12 (16)	5 (7)	1 (1)	3 (4)	1 (1)	5 (7)
<b>Left Rot.</b>	7 (10)	1 (1)	15 (21)	1 (1)	0 (0)	6 (8)	0 (0)	17 (23)	3 (4)	3 (4)	4 (6)	7 (10)	3 (4)	0 (0)	6 (8)
<b>Right Rot.</b>	8 (11)	2 (3)	2 (3)	13 (18)	1 (1)	5 (7)	0 (0)	2 (3)	18 (24)	3 (4)	2 (3)	8 (11)	0 (0)	3 (4)	6 (8)
Pain with movement															
	<b>Yes</b>				<b>No</b>				<b>Not tested</b>						
<b>Flexion</b>	17 (23)				53 (73)				3 (4)						
<b>Extension</b>	16 (22)				54 (74)				3 (4)						
<b>Rotation (Right)</b>	12 (16)				58 (80)				3 (4)						
<b>Rotation (Left)</b>	10 (14)				60 (82)				3 (4)						
<b>Side bending (Right)</b>	13 (18)				57 (78)				3 (4)						
<b>Side bending (Left)</b>	11 (15)				59 (81)				3 (4)						

SB = Side bending, Rot. = Rotation

movement in two directions whereas 17% demonstrated pain in more than two directions of movement. Fifty-six percent of patients demonstrated no pain with cervical spine movements.

Seventy-one percent of patients demonstrated hypomobility exclusively in upper cervical spine

segments (C0- C2), 52% demonstrated hypomobility in more than two spinal segments and 4% demonstrated hypomobility only in lower cervical spine segments (C3-C7). In terms of thoracic mobility, T1-T4 segments were most commonly evaluated and demonstrated hypomobility in 60% of patients. Similarly, first rib was most commonly evaluated

**Table 6. Segmental spine and rib mobility results.**

N (%)					
	Hypomobility	Hypermobility	Normal	Not tested	Mixed findings
<b>All cervical segments</b>	19 (26)	1 (1)	8 (11)	2 (3)	43 (59)
<b>Upper cervical spine only (C0-C1 &amp; C1-C2)</b>	52 (71)	2 (3)	14 (19)	5 (7)	NA
<b>Lower cervical spine only (C3-C7)</b>	3 (4)	3 (4)	34 (47)	4 (5)	29 (40)
<b>More than two spinal segments</b>	38 (52)	3 (4)	NA	4 (5)	28 (39)
<b>T1-T4</b>	43 (60)	1 (1)	17 (23)	12 (16)	NA
<b>T5-T8</b>	15 (21)	1 (1)	16 (22)	41 (56)	NA
<b>T9-T12</b>	13 (18)	1 (1)	17 (23)	42 (58)	NA
<b>First rib</b>	30 (41)	0 (0)	12 (17)	31 (42)	NA
<b>Second rib</b>	10 (14)	0 (0)	16 (22)	47 (64)	NA
NA = Not applicable					

and 41% of patients demonstrated hypomobility (Table 6).

### Muscle strength and endurance:

Manual muscle testing data revealed that rhomboids were the most common muscles to demonstrate weakness i.e. muscle strength < grade 5 (35%) followed closely by middle (30%) and lower trapezius (31%) whereas upper trapezius was found to be the muscle group that demonstrated weakness in least number of patients (3%) (Table 7). The neck flexor endurance was abnormal in 40% of patients indicating poor endurance (Table 7). Since CCFT was the least common of the strength measures used (performed in only 4% of patients), the data was not considered adequate to draw meaningful inferences and hence not reported.

### Upper extremity radicular symptoms:

None of the patients demonstrated upper extremity radicular symptoms on Spurling test.

## DISCUSSION

High prevalence of cervical spine impairments was observed in this study of young patients post-concussion, with over 90% of patients demonstrating impairments in three or more categories. Most commonly observed impairments were noted in muscle tension,

**Table 7. Muscle strength and endurance results.**

N (%)				
Strength				
Muscle group	Abnormal	Normal	Not tested	Missing
<b>Upper trapezius</b>	2 (3)	24 (32)	47 (64)	1 (1)
<b>Middle trapezius</b>	22 (30)	7 (10)	44 (59)	1 (1)
<b>Lower trapezius</b>	23 (31)	5 (7)	45 (61)	1 (1)
<b>Rhomboids</b>	26 (35)	3 (4)	43 (58)	2 (3)
<b>Longissimus colli</b>	8 (11)	6 (8)	59 (80)	1 (1)
<b>Sternocleidomastoid</b>	9 (12)	5 (7)	29 (80)	1 (1)
Endurance				
<b>Neck flexor endurance test</b>	29 (40)	12 (16)	32 (44)	NA
NA = Not applicable				

joint mobility, and muscle strength. The categories of impairments examined in this cohort are consistent with the impairments reported in the most recent clinical practice guidelines for neck pain.<sup>30</sup>

Cervical spine injuries may independently contribute to many concussion symptoms including headaches, dizziness, neck pain, disturbance of concentration or memory, irritability, sleep disturbance, and fatigue.<sup>13</sup> The findings of this study revealed that over 70% of the patients had upper cervical spine mobility impairments. Similar findings were noted

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in a recent preliminary report that observed range of motion and segmental mobility impairments primarily affecting the upper cervical spine.<sup>28</sup> Upper cervical spine (C1- C3) has previously been reported to contribute to most of the cervicogenic symptoms observed following trauma including cervicogenic headaches, dizziness and unsteadiness.<sup>13,14,72</sup> Factors including cervical zygapophyseal joint mobility impairments and abnormal somatosensory inputs from upper cervical and trigeminal sensory afferents may explain headaches and dizziness following cervical spine injury.<sup>12-14</sup> High occurrence of headaches (84%) and dizziness (57%) among the patients in this study warrants detailed examination of upper cervical spine mobility in this population.

High pain intensity and high NDI scores have been identified as risk factors for having persistent symptoms if present after acute whiplash.<sup>30</sup> Pain associated with cervical spine movement could be attributed to altered axio-skeletal muscle activity and dysfunction in scapular mobility as reported by Helgadottir and colleagues<sup>73</sup> in young adults with whiplash injury.<sup>73</sup> Moderate to high level evidence exists for evaluation of neck pain intensity and collecting NDI scores to establish prognosis following whiplash.<sup>30</sup> In this study, 40% of patients demonstrated moderate to severe disability on NDI thereby indicating the lasting perception of disability following concussion. However, it is important to note that NDI has not been validated in individuals younger than 18 years of age and may not capture the true extent of cervical disability perceived by adolescents.

Daenen and colleagues<sup>74</sup> reported that alterations in muscle activity continue to exist over time following whiplash trauma, indicating the need of strength and endurance evaluation for treatment and prevention of re-injury.<sup>61,74</sup> In this sample, muscle strength and endurance deficits were observed among 40% of the patients. Although the clinical practice guidelines on neck pain recommended the use of cranial-cervical flexion and neck flexor muscle endurance test in patients with all types of neck pain and movement-coordination impairments,<sup>30</sup> these tests were not frequently performed by the treating therapists. CCFT and NFET were not commonly tested due to the acute nature of the injury, increased pain level and increased muscle guarding upon testing.

Of the patients that were tested for JPET (n = 21) in this study, 14 were found to have impaired position sense. The control of head position has been reported to be affected when neck proprioceptive information is inaccurate, which has been observed in patients with chronic non-traumatic neck pain as well as with whiplash-type injuries.<sup>12,75</sup> Impairments in position sense may contribute to dizziness, disequilibrium and impaired postural control.<sup>75</sup> The high percentage (66%) of abnormal joint position sense in those participants that were tested may warrant consideration for including this test in evaluation of this population. However, completion of JPET in the first visit may have not been feasible, especially in patients with other various documented impairments.

Additionally, active range of motion at the cervical spine has been associated with both proprioception and oculomotor performance in adults with whiplash-type injuries, thereby indicating a role of zygapophyseal joints in proprioceptive dysfunction.<sup>76</sup> Increased muscle tension of the cervical spine musculature, may also result in impaired proprioceptive signals.<sup>76</sup> This close association of cervical proprioceptive inputs to the contribution of head position and equilibrium reinforces the need for detection of cervical joint position error to determine the source of balance problems and initiate appropriate intervention strategies (cervical or vestibular).

Previous literature has indicated that children and adolescents have lesser cervical spine mobility as compared to young adults.<sup>77,78</sup> Similar findings were observed in this study with over 70% of participants demonstrating hypomobility. However, the lack of a perfect relationship between range of motion deficit and the results of segmental mobility testing can be explained by various reasons. First, many patients presented with hypomobility in some segments and hypermobility in others, which may have not affected the overall ROM measurement results. Cervical spine segments adjacent to hypomobile segments may become hypermobile, creating an unimpaired active range of motion.<sup>78</sup> Second, range of motion can be influenced by factors other than segmental mobility. These factors can include pain, altered posture, and limited cervical muscle extensibility and motor control deficits.<sup>79,80</sup>

It was also noteworthy that none of the patients tested positive for alar or transverse ligament instability and/or radicular symptoms during physical therapy evaluation in this study. Tests for ligamentous integrity have been reported to have sufficient specificity but demonstrate high variability in sensitivity, and therefore need to be interpreted with caution.<sup>38</sup>

Several limitations were associated with this study. Many of the tests employed in this study are subjective and may not demonstrate ideal reliability. Although the therapists underwent training to standardize administration of tests for quality assurance and to improve inter-rater reliability, it is possible that the inherently subjective nature of these tests influenced the findings of this study. Variations in the choice of tests and in grading and interpretation of the tests administered at initial evaluation could have influenced the prevalence of impairments found in this study. Additionally, pain associated with segmental mobility could not be documented in this study due to inconsistencies with documentation. Since reproduction of symptoms is important for localizing impaired segments,<sup>56,57</sup> future studies should focus on pain assessment with segmental mobility.

The cervical physical therapy examination was impairment-guided and was often dictated by injury acuity and patient's tolerance to testing. Since patients varied in injury acuity, tolerance to assessment, and in exhibited impairments, not all tests were conducted on all patients. This may have biased the reported prevalence of the impairments by over-representing impairments on tests that were administered more often and under-representing the prevalence of impairments identified in tests that were done less often. Additionally, assessment of radiculopathy using only the Spurling test instead of utilizing the Wainner's test item cluster<sup>70</sup> may have led to underrepresentation of the prevalence of radiculopathy in the sample. This study reported the percentage of patients in which a particular test was not administered. Therefore, clinicians are encouraged to take that in consideration when interpreting the prevalence of cervical impairments reported in this study as the true percentage of impairments maybe greater had they been tested in all subjects.

Given the cross-sectional design of this study, it is unclear if exhibited cervical impairments (i.e. limited

ROM, limited segmental mobility, increased muscle tension and altered posture) were present before concussion or if they were attributable to the concussion. Although it is possible that cervical impairments exist in non-concussed children,<sup>81-83</sup> their presence in post-concussion children may contribute to post concussion symptoms. Therefore, although a cause and effect relationship cannot be ascertained between cervical impairments and concussion, targeted assessment and rehabilitation of cervical impairments after concussion is warranted.<sup>21,22,26</sup>

Impairments identified in this study are subjected to sample bias and may not represent the prevalence of cervical impairments in the wide spectrum of concussion patients. Nonetheless, given the clear link between common concussion symptoms and cervical impairments,<sup>7,12</sup> findings of this study can provide a foundation for clinicians aiming to identify cervical impairments in patients with concussion.

## CONCLUSIONS

High prevalence of cervical spine impairments was observed in the subjects included in this study with muscle tension, joint mobility, and muscle strength being most commonly affected post-concussion. The findings of this study provide preliminary data to support the framework for a cervical spine evaluation tool in children and adolescents following concussion.

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